Flora W. Patterson

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COMBATING THE BLACK ROT OF CABBAGE BY THE REMOVAL OF AFFECTED LEAVES.

F. C. STEWART AND H. A. HARDING.

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COMBATING THE BLACK ROT OF CABBAGE BY THE REMOVAL OF AFFECTED LEAVES.

F. C. STEWART AND H. A. HARDING.

SUMMARY.

Black rot is destructive to cabbage and cauliflower in New York. It is a bacterial disease the chief diagnostic character of which is the appearance of black streaks in the woody portion of the stem and in the leaf-stalks.

As a preventive of the disease, other investigators have recommended the leaf-pulling treatment which consists in removing all affected leaves at frequent intervals. During the past four years the writers have made practical field tests of this treatment and found it to be worthless.

Each season the experiment field was one acre in extent, one-half being treated and the other half used as a check. During the first three seasons there was not enough black rot to give the treatment a fair trial; but in 1902 there was a moderate attack of the disease. All diseased leaves were carefully removed once a week from July 22 to September 16. The treatment not only failed to check the disease but reduced the yield by 5,285 lbs. on one-half acre, or at the rate of 5¼ tons per acre.

The treatment fails for the following reasons: (1) The removal of so many leaves checks the growth of the

plants. In a supplementary experiment made in 1900 the removal of 10 leaves (one or two each week) from each plant reduced the yield by 42.8 per ct., or at the rate of three tons per acre (page 64); (2) Infection occurs through the roots as well as by the way of the leaves; (3) Infection may occur at the base of the leaf close to the stem and get into the stem unobserved; (4) The germs of the disease are so widely and so abundantly distributed that it is useless to try to stamp out the disease by the removal of diseased material.

No successful method of combating the disease is known. Further experiments on treatment are in progress; also, investigations on the mode of infection and dissemination, as it is believed that these fundamental problems must be solved before much progress can be made toward the control of the disease.

INTRODUCTION.

The principal object of this bulletin is to give an account of some recent field experiments on the treatment of the black rot[1] of cabbage by the prompt removal of affected leaves. This line of treatment, having been wholly unsuccessful, will hereafter be abandoned; but experiments on the treatment of the disease, on both cabbage and cauliflower, will be continued along other lines. There are in progress also, supplementary investigations on the disease itself and on a soft rot[2] frequently associated with it. Inasmuch as other and more exhaustive publications on black rot are contemplated by the writers only a brief account of the disease will be given at this time. Those wishing a more complete account should consult Wis. Agr. Exp. Sta. Bul. 65, A Bacterial Rot of Cabbage and Allied Plants; and U. S. Dep't of Agr. Farmers' Bul. 68, The Black Rot of the Cabbage.

THE DISEASE.

ECONOMIC IMPORTANCE IN NEW YORK.

An epidemic of black rot on cabbage and cauliflower occurred on Long Island in 1895–6 and in 1898 the cabbage raising sections in the central and western portions of the State were swept by this trouble. In some cases entire fields were totally destroyed by this disease and the loss throughout the State amounted to many thousands of dollars. Since 1898, while the damage has been less universal, there have been each year isolated fields where the loss was considerable. The financial loss upon cabbage occurs principally upon the later varieties, the Danish being especially subject to attack.

PREVIOUS INVESTIGATIONS.

This disease of cabbage and cauliflower was first reported by Garman[2a] in 1890, was studied by one of us on Long Island in

[1] *Pseudomonas campestris* (Pam.) Smith.

[2] A preliminary report of the investigations on soft rot was published in *Science*, N. S., **16**: 314–315. Aug. 22, 1902.

[2a] Garman, H. A Bacterial Disease of Cabbage. Ky. Exp. Stat. Rep. 1890: 43.

1895, was described by H. L. Russell at the Springfield meeting of the American Association for the Advancement of Science in August, 1895, and later was studied extensively at the Wisconsin Agricultural Experiment Station and at the Department of Agriculture at Washington. Extended accounts of the disease and its cause were published by E. F. Smith in the *Centralblatt für Bakteriologie*, II Abteilung, Vol. 3, and in Farmer's Bulletin 68 of the Department of Agriculture, as well as by Russell & Harding in Bulletin 65 of the Wisconsin Agricultural Experiment Station.

APPEARANCE OF AFFECTED PLANTS.

The first evidence of disease usually appears in the latter part of July when the more advanced plants of late cabbage are beginning to form heads. The first symptoms of an outbreak are easily recognized on a hot, dry afternoon when a number of the plants will appear wilted and lighter green in color. A cross section of the stem of these plants near the ground shows that many of the water-carrying fibro-vascular bundles are black; and on splitting the stem these black lines can be followed down to the withered extremity of the tap root. A diseased condition of any considerable number of these bundles curtails the water supply and when atmospheric conditions are favorable for rapid evaporation from the leaves the latter quickly wilt.

The upward movement of the water carries the disease along the bundles out into the leaves. As soon as the bundles supplying any considerable portion of a leaf become diseased that part of the leaf dies for lack of water. The blade of the leaf becomes light brown and has a texture like parchment. It is semi-transparent and when closely examined the network of fine veinlets which have been turned black by the disease stands out sharply in the brown background.

Early in August the disease commonly manifests itself in another form. Brown spots appear at the margin of many of the leaves (see Plate I) especially of those which come in contact with the soil. These brown areas spread toward the center of the leaf and a close examination shows the fine veins to be blackened. In from one to three weeks, depending on circumstances, the

PLATE I.—CABBAGE LEAF AFFECTED WITH BLACK ROT, WATER PORE INFECTIONS.

disease usually reaches the stem of the plant. The progress of the disease from this point is identical with that brought about by infection through the root.

In either form of infection the most reliable diagnostic character of the disease is the blackening of the fibro-vascular bundles. These bundles may be readily inspected by cutting across the leaf petiole or the stem.

The failure to supply sufficient water checks growth and often results in the death of the plant. The fibro-vascular bundles do not branch freely in the stem and in cases where the disease gains a foothold only on one side of the plant the growth on that side is retarded so as to produce a marked curvature. The lower leaves turn brown and drop off, but when the plant succeeds in forming a head the upper leaves are held in place and often turn black and decay thus destroying the commercial value of the head.

The extreme variation in the activity of this disease in different years depends largely upon weather conditions. A combination of abundant moisture with high temperature during August and September is favorable for an epidemic.

CAUSED BY BACTERIA.

The blackening of the fibro-vascular bundles and the accompanying decrease in the water flow is due to the growth in the tissue of a bacterium known as *Pseudomonas campestris* (Pam.) Smith. This is the fact in connection with the disease which has been most carefully established. The tissue of healthy plants is free from germ life, but large numbers of *Pseudomonas campestris* are constantly found in these blackened bundles. Germs obtained in this way from diseased plants at such widely separated points as Wisconsin, New York and Switzerland were carefully studied and found to be of this species.[3] When pure cultures of *P. campestris* were introduced into the stem of healthy plants under circumstances which prevented the entrance of other forms the characteristic phenomena of the disease were reproduced.

[3] Harding, H. A., Die schwarze Fäulnis des Kohls und verwandter Pflanzen, eine in Europa weit verbreitete bakterielle Pflanzenkrankheit. *Centralbl. f. Bakt.*, II Abt., **6**: 305. 1900.

From blackened bundles resulting from these artificial inoculations and at considerable distances from the point of infection, in tissue which had been formed subsequent to the inoculation, pure cultures of *P. campestris* were obtained. This completes the proof considered necessary to establish the causal relation of an organism to a given disease.

MODE OF INFECTION.

There are at least three avenues through which these germs may gain access to the plants:

(1) At the time of transplanting into the field some of the roots are broken, exposing the ends of the fibro-vascular bundles to the attack of *P. campestris* in the soil. The plants which wilt badly within a few weeks often have many black fibro-vascular bundles in the stem when there is no evidence of the disease in the leaves. (See page 61.) This mode of infection seems to be most active during the early life of the plants.

(2) Insects, by eating the leaf tissue, expose the cut ends of the fibro-vascular bundles and either infect these directly by their jaws or leave the surfaces in condition to be infected from other sources. This avenue of infection appears to be more important with cauliflower than with cabbage, but in either case is of secondary importance.

(3) Under favorable atmospheric conditions the water pores at the margin of the leaves exude liquid. Any germs which find their way into these drops after swimming back through the opening of the water pore find themselves at the termination of a fibro-vascular bundle. A great majority of the infections occurring during the month of August can be traced to this source. Sometimes as many as a hundred cases of this form of infection may be seen on a single large plant.

MODE OF DISSEMINATION.

The natural habitat of *P. campestris* and the ways in which it is distributed from plant to plant have not been satisfactorily worked out. Observations made in connection with root infection makes it probable that *P. campestris* is able to live in the

soil in competition with the other forms found there. However, several attempts to isolate this organism from soil supposed to be infected have failed. On account of the large number of other forms present in soil a small number of *P. campestris* would be easily overlooked.

The first leaf infections take place in the outer leaves, which often come in contact with the soil. Later, infection occurs on the more central leaves which could hardly have been directly infected in this way. In the latter case the germs must have been carried to the water pores either by insects or air currents. In either case the germs would have been exposed to a considerable amount of dessication, something which they seem to be little fitted to withstand.

So far as is definitely known the transfer of the disease from one field to another is connected with the transfer of portions of diseased plants. The wind carries parts of diseased leaves for considerable distances. Along water courses in times of freshets the water deposits both soil and plant remains. By feeding to animals or otherwise disposing of rubbish, parts of diseased plants are often carried out upon new fields.

The disease sometimes appears in fields where none of the cabbage family has been cultivated for many years and where no known mode of infection is active.

EXPERIMENTS ON PREVENTION BY THE REMOVAL OF AFFECTED LEAVES.

WHY UNDERTAKEN.

Black rot being so destructive in New York in the season of 1898, there was an urgent demand from farmers for information concerning methods of combating it; and it became imperative that the Station should undertake some experiments on the treatment of the disease.

Both Russell[4] and Smith[5] had suggested the removal of affected leaves as being a promising line of treatment. They made some

[4] Russell, H. L. A Bacterial Rot of Cabbage and Allied Plants. Wis. Agr. Exp. Sta. Bul. 65 : 38, 39.

[5] Smith, Erwin F. The Black Rot of the Cabbage. U. S. Dep't of Agr. Farmers' Bul. 68 : 14.

experiments, the results of which indicated that the disease might be controlled in this way. Russell[6] says:

On the horticultural grounds at the University, cauliflower was planted on soil that had borne a similar crop the previous year, and one which was somewhat affected with the rot. This field was allowed to develop in the usual manner until September of this year. By the first of the month, the patch began to show evidence that the disease was pretty generally distributed. At this date it was divided into four sections and from alternate sections the attempt was made to stop the disease by removing the affected leaves. The other two sections were left under natural conditions and no attempt was made to check the spread of the malady. The result of this experiment was that the disease was held completely in check. Several plants became infected subsequent to the removal of the diseased leaves, but by removing all of these later the further progress of the disease was brought to a standstill.

The continued spread of the disease in the uncontrolled sections showed that the disease organism was being thoroughly distributed and therefore the failure to spread was not due to absence of disease virus.

Another experiment was also carried out on a larger scale under commercial conditions. A field of about three acres of cabbage near Berryville, Wis., was noted that had been planted on new ground that had never had cabbage on it before. When first observed on September 1st, of this year, the cabbage rot was just beginning to make its appearance. In some cases where the plants were small the disease had established itself in the stem, but in the majority of cases only individual leaves were affected. At our suggestion, the owner decided to remove all diseased leaves and badly affected plants in order to see whether the progress of the trouble might not be retarded. The result of this was that the repressive measures used kept the disease well in check. The patch was only fifteen rods distant from another field that was very severely affected, and of course the seeds of the disease were continually being distributed by means of the wind. The disease made but slow headway as the season was unusually dry. Yet under the same atmospheric and soil conditions, in another large patch in which no repressive measures were attempted the disease developed severely.

Smith[7] says:

This method was tried by the writer in August, 1897, on about four hundred plants, with very satisfactory results, four-fifths of the heads being free from the disease when harvested in November. The one-fifth may have been diseased in the stem at the time the leaves were broken off, or may have subsequently contracted the disease through other leaves.

These experiments were all faulty in that no account was taken of the all-important factor of yield. In Smith's experiment no check is mentioned and Russell's cabbage experiment was also without a proper check.

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[6] Russell, H. L. Loc. cit.

[7] Smith, Erwin F. Loc. cit.

However, the results appeared encouraging and from theoretical considerations it seemed reasonable to expect that the leaf-pulling treatment might be successful. Moreover, it was, at that time, the only line of treatment which had been suggested.

Accordingly, the writers set out to test it thoroughly and determine definitely whether it is a preventive of the disease, and also whether it is a profitable operation under commercial conditions.

METHOD OF TREATMENT DESCRIBED.

In general, the method of treatment is as follows:

The plants are carefully watched for the first appearance of the disease, which usually occurs about August 1. Thereafter, the field is gone over, row by row, once a week, and every leaf showing signs of the disease is broken off and carried out of the field. Whenever there is found a plant in which the disease has already gotten into the stem, as shown by the presence of black streaks in the basal portion of the leaf stalks, such plant is promptly removed from the field. It has been the practice of the writers to carry a large market basket into which the diseased leaves are placed as fast as gathered. When the basket is filled it is carried to the margin of the field and emptied.

It may be stated here that in the experiments described in this bulletin the work of removing the diseased leaves was not entrusted to laborers. Most of it was done by the writers themselves and the remainder by Messrs. F. M. Rolfs and H. J. Eustace, assistants in the Botanical Department, and L. A. Rogers and J. F. Nicholson, assistants in the Bacteriological Department. The writers wish to thank these gentlemen for their efficient assistance.

THEORY OF THE TREATMENT.

In many cases the disease starts at the margin of the leaf (see Plate I); sometimes, also, in leaf wounds made by insects, and then passes downward along the fibro-vascular bundles (veins) into the stem of the plant.

As a rule, several days are required for the disease to reach the stem. Once the disease is within the stem it is beyond con-

trol and the plant is likely to be ruined; but if the affected leaf were removed before the disease had reached the stem the plant would be saved. Moreover, the diseased leaves, if not removed, become a source of infection to neighboring plants, particularly when the affected plant dies and decays. Hence, the seeming importance of carrying all affected leaves and plants from the field.

Briefly stated, the treatment aims at two things: (1) To save plants already slightly affected; and (2) To prevent the spread of the disease by the removal of the causal organism.

EXPERIMENTS PRIOR TO 1902.

In 1899.—The field selected for the experiment was one on which the cabbage crop had been practically ruined by black rot the preceding season. It contained exactly one acre, was trapezoidal in shape and about twice as long as wide. It lay on river bottom land near Phelps, N. Y., on the farm of Mr. David White. The soil was a sandy loam well adapted to the growth of cabbage.

The plants were of the variety Danish Ball Head, set June 15, 33 inches apart each way. They were carefully watched in the seed bed and showed no signs of black rot at the time of transplanting.

The field was divided crosswise into two equal parts each containing one-half acre. On one half-acre all affected leaves were to be removed once a week throughout the season, while the other half acre was to serve as a check.

On the half-acre to be treated one affected leaf was found July 20 and by July 28 there were about 20 leaves with one or more small brown marginal areas of uncertain origin; but the first real outbreak of black rot was noted August 4, on which date the first treatment was made. For each treatment a record was kept of the time consumed, the number of leaves removed, the number of points of infection and the number of plants removed because of disease in the stem. These data are shown in the following table:

TABLE I.—DATA OF THE CABBAGE ROT EXPERIMENT IN 1899.

Date of treatment.	Time consumed.	Diseased leaves removed.	Points of infection.	Whole plants removed.
	Hrs.	*No.*	*No.*	*No.*
August 4	1½	181	408	0
" 10	1½	195	299	0
" 17	1½	59	72	2
" 25	1½	47	75	0
" 31	1½	52	68	7
September 9	1¾	46	54	17
" 15	1	36	46	7
" 22	1	18	25	7
Totals	11¼	634	1,047	40

In addition to the 634 affected leaves there were removed a considerable number of leaves showing brown marginal areas which, upon close examination, were found to be due to causes other than black rot. In four seasons' experience the writers have found that in order to be on the safe side it is always necessary to remove a good many leaves which may not be really affected with black rot but which present symptoms so similar that a close examination is required for a correct diagnosis.

The principal part of the crop was harvested and marketed on November 4 and 6; but some immature heads were allowed to stand until November 21. For each half acre a record was kept of the number of marketable heads and their weight; also of the number of heads showing well defined symptoms of black rot, those showing traces of black rot and those with soft rot in the stem. These data are given in the following table:

TABLE II.—RESULTS OF CABBAGE ROT EXPERIMENT IN 1899.

Quality.	Treated half-acre.		Check half-acre.	
	Heads.	Weight.	Heads.	Weight.
	No.	*Lbs.*	*No.*	*Lbs*
Marketable (1st cutting)	2,200	13,710	1,835	9,750
" (2d cutting)	200	200	503	500
" (total)	2,400	13,910	2,338	10,250
Showing black rot, definitely	11		11	
" " " traces	6		6	
" soft rot in stem	5		6	

The treated half-acre yielded 2,660 lbs. more than the check. This is at the rate of 5,320 lbs. or over 2½ tons per acre. However, this difference can not have been the result of the treatment. Close observation led to the conclusion that neither the check nor the treated half-acre was materially injured by the disease. The plants on the check, which was next the river, were considerably injured by muskrats and it is believed that the damage was sufficient to account for the difference in yield.

Because of the small amount of disease this experiment teaches very little as to the value of the treatment; but it does show that it is possible to secure a fair crop of cabbage (12 tons per acre) on land on which the disease has been previously destructive.

In 1900.—The field used for the experiment in 1900 was the same as that used in 1899. The variety of cabbage, Danish Ball Head, was also the same. Previous to planting, the seed was soaked for 15 minutes in a 1-1000 corrosive sublimate solution.[8] The seedlings were inspected June 19 and seemed to be wholly free from black rot. They were transplanted July 3 and 4. As in 1899, the field was divided crosswise into two equal parts—one part to be treated and the other part to be used for a check.

The first treatment was made on August 9 and repeated once a week thereafter until September 19. In all, seven treatments were made. At each treatment all leaves showing any indication of the disease whatever were removed and placed in a pile at the margin of the field. Afterward, they were counted and carefully examined for evidences of black rot. A record was kept of the number of leaves showing definite signs of black rot; also of the number of whole plants which it was necessary to remove because of the disease having gained access to the stem. All these data are given in the following table:

[8] The seed was treated with corrosive sublimate as a precaution against possible infection by germs on the seed. In experiments made by the writers cabbage seed soaked for one hour in a 1-1000 solution of corrosive sublimate and afterward rinsed with distilled water has germinated quite as well as untreated seed. It is safe to say that a 15-minute treatment of this kind will result in no injury to the seed.

TABLE III.—DATA OF THE CABBAGE ROT EXPERIMENT IN 1900.

Date of treatment.	Leaves removed.			Whole plants removed.
	Total.	Affected with black rot.	Not affected with black rot.	
	No.	*No.*	*No.*	*No.*
August 9	150	71	79	6
" 15	165	124	41	4
" 23	512	206	306	10
" 30	205	87	118	3
September 5	454	150	304	11
" 12	747	143	604	11
" 19	243	143	100	5
Totals	2,476	924	1.552	50

The crop was harvested November 12. A record was kept of the number of marketable heads and their weight; also, of the number of heads too small for market, but no account was taken of plants which failed to head. All heads, both marketable and small, were examined for evidences of black rot. These data are fully shown in the following table:

TABLE IV.—RESULTS OF CABBAGE ROT EXPERIMENT IN 1900.

Quality.	Treated half-acre.		Check half-acre.	
	Heads.	Weight.	Heads.	Weight.
	No.	*Lbs.*	*No.*	*Lbs.*
Marketable	1,452	6,680	1,225	4,500
Small	1,069		1,273	
Affected with black rot	60		142	

As in 1899, the greater yield of the treated half-acre was not the result of the treatment. Again, the check was the most injured by the muskrats. Another thing which reduced the yield on the check was the supplementary leaf-pulling experiment conducted there. (See page 63.) On account of this experiment the number of marketable heads was reduced by 207 and the yield by 1151 lbs., which should be added to the figures given in the above table. Thus corrected, the yield of the check would be 1432 marketable heads having a weight of 5651 lbs.

Black rot, although somewhat more abundant than in 1899, was not sufficiently destructive to affect the yield. Consequently, the experiment was again a failure so far as throwing light on the value of the treatment is concerned. This season the plants were considerably injured by drought.

In 1901.—This year the location of the experiment field was changed. An acre was laid off in the center of a field of Danish Ball Head cabbage a few rods from the former field and on soil of the same character but a little higher and drier. The plants had been set June 21. The field was divided into two equal parts, one part being treated and the other a check. The treatments were made weekly commencing August 9 and closing September 21.

The plants grew vigorously from the start. Although black rot made its appearance at the usual time, the first week in August, it did no damage worth mentioning and for the third time the experiment failed of results because of a lack of the disease. During the whole season there appeared upon the treated half acre only 150 affected leaves and 12 plants affected in the stem.

Owing to trouble with a produce dealer to whom the crop was sold the Station was prevented from harvesting the cabbages until they had been ruined by freezing and consequently no record of the yield was obtained; but it was estimated to be from 13 to 16 tons.

EXPERIMENT IN 1902.

Having, for three consecutive seasons, failed to secure a sufficient amount of the disease, it was decided to adopt a new method of selecting a field for the experiment. Commencing about July 10, cabbage fields in the vicinity of Geneva and Phelps were carefully watched for the appearance of black rot, the plan being to locate a field in which there promised to be an epidemic of the disease and then arrange to make the experiment there.

A suitable field was found, July 16, on a farm near Phelps, leased by Mr. Charles D. White. Many leaves were already showing unmistakable signs of infection, and it seemed likely that there would be a serious outbreak of black rot.

The plants had been set, 33 inches apart each way, about June 25. On one side of the field there was laid off an exact acre, twice as long as wide, and containing 54 rows of 108 plants each. The acre was so located as to cover 27 rows of each of two varieties, Danish Ball Head and Henderson's Succession. It was divided, crosswise, into two equal parts—one part to be treated and the other used as a check. By this arrangement each half acre contained 27 rows (54 plants each) of Danish Ball Head and 27 rows of Henderson's Succession. (See the accompanying diagram.)

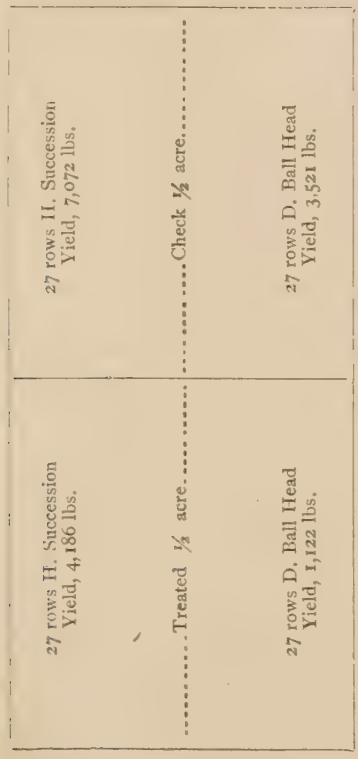

Diagram I.—Showing Shape, Arrangement and Yield of Plats in the Cabbage Rot Experiment at Phelps in 1902.

From the plants on the treated half-acre all diseased leaves were removed once a week on the following dates: July 22 and 29; August 5, 12, 19 and 26; September 2, 9 and 16. The total amount of time required to make these nine treatments on one half-acre was 46½ hours for one man.

At the time of the first treatment, July 22, it was estimated that 33 per ct. of all the plants were showing more or less leaf infection. From this time until well into September the disease continued active. At each treatment there were multitudes of diseased leaves to be found notwithstanding every diseased leaf had been removed one week previous. In spite of all that could be done large numbers of new infections continued to appear. For a time every plant found to be affected in the stem was removed as in previous experiments; but this was soon abandoned as it was plain that it would result in a serious depletion of the treated plat. Although the disease was so abundant that on the check plat scarcely a single plant wholly free from it could be found by September 2, only a few plants were completely ruined by it, and the attack is to be regarded as only a moderate one.[9] This view is supported by the yield on the check plat which was at the rate of over ten tons per acre.

The 27 rows of Henderson's Succession were harvested October 13 and the 27 rows of Danish Ball Head, November 8. The results are shown in the following table:

[9] Black rot is not so certainly fatal as one might infer from the literature of the subject. A good yield of cabbage may often be obtained from fields in which almost every plant shows more or less infection. This may be true even when the infection occurs early in the season. Plants infected within a month after transplanting may live to produce marketable heads of good size. Even plants in which the disease has gained access to the main stem often produce marketable heads and the removal of such plants causes unnecessary loss. The rapidity with which the disease progresses within the plant is greatly influenced by weather conditions and the condition of the plant.

Black rot appeared abundantly in many fields in the vicinity of Geneva about August 1, 1899, but drought during the next two months decreased the succulence of the plants and seemed to check the progress of the disease.

During the season of 1902 there was an abundance of moisture, but the temperature was unusually low, and while nearly every plant in our experiment field contracted the disease few were destroyed.

TABLE V.—RESULTS OF CABBAGE ROT EXPERIMENT IN 1902.

Variety.	Treated half-acre, one half to each variety.		Check half-acre, one-half to each variety.	
	Heads.	Weight.	Heads.	Weight.
	No.	*Lbs.*	*No.*	*Lbs.*
Henderson's Succession	894	4,186	1,175	7,072
Danish Ball Head	302	1,122	761	3,521
Total	1,196	5,308	1,936	10,593

The treatment resulted in a loss of 5285 lbs., which is at the rate of 5 1-4 tons per acre.

Although the affected heads were not counted there were apparently about the same number on the treated portion as on the check. On both plats a few heads were affected with soft rot externally and a few with soft rot in the stem.

The treatment was even more than a complete failure. It not only failed to prevent the disease, but actually reduced the yield by 5¼ tons per acre. This fact, taken in connection with the expense of the treatment, which was $11.62 per acre (counting labor at 12½ cents per hour), makes the treatment highly unprofitable. The worthlessness of the leaf-pulling treatment is so thoroughly demonstrated by this experiment that further experimentation along this line has been abandoned.

WHY THE LEAF-PULLING TREATMENT FAILS.

Removal of leaves checks the formation of heads.—Even if black rot could be controlled by the removal of diseased leaves the treatment could not be made a profitable operation for the reason that it reduces the yield. The removal of affected leaves checks the growth of the heads. In order that the treatment may be effective it is necessary to remove all affected leaves, even those showing only traces of infection and also many others not really affected. (See page 53 and Table III.) The loss of so many leaves is a great drain upon the plants. If these leaves were not removed they would continue to perform their function for a considerable length of time in spite of the fact that they were

diseased. Very frequently, it is necessary to remove large leaves having an area of 60 to 80 square inches because of a single diseased spot, perhaps an inch square, on the margin.[10] It might be two or three weeks or even more before such a spot would enlarge sufficiently to seriously impair the usefulness of the leaf.

In the experiment made in 1902 (page 56) the plants on the treated half-acre had a trimmed-up appearance due to the removal of many diseased leaves. This was very noticeable. Toward the close of the season many plants were entirely destitute of stem leaves. As a consequence, the heads were small and it was plain that the removal of the leaves had been decidedly injurious. This opinion is fully sustained by the fact that the yield of the treated half-acre was at the rate of 5¼ tons per acre less than that of the check. (See Table V, page 59.)

Infection occurs through the roots as well as on the leaves.—Russell[11] and Smith[12] demonstrated beyond doubt that infection very frequently occurs through the water pores at the margins of the leaves and, sometimes, also in leaf wounds made by insects. The leaf-pulling treatment is based on the assumption that these are the chief modes of infection. In fact no other mode of infection has been seriously considered, although there is a popular opinion among farmers that the disease is often communicated through the seed.

Field observations made in 1901 led the writers to suspect that infection may also occur through the roots. This suspicion was greatly strengthened by observations made on the experiment field at Phelps in 1902. Within a month from the time the plants were transplanted many of them were showing signs of infection in the stem without any leaf symptoms whatever. It was ob-

[10] The question may be asked, Why not break off only as much of the leaf as may be necessary to remove the diseased area? This is impractical for two reasons: (1) It consumes too much time; and (2) The writers have observed that in a large percentage of the cases in which this has been done the broken leaf-margin has promptly become reinfected, possibly from germs on the hand of the operator.

[11] Russell, H. L. Loc. cit. pp. 27–30.

[12] Smith, Erwin F. *Pseudomonas campestris* (Pammel). The Cause of a Brown Rot in Cruciferous Plants. *Centralbl. f. Bakt., Parasitenk.* etc., II Abt., **3**: 409–413.

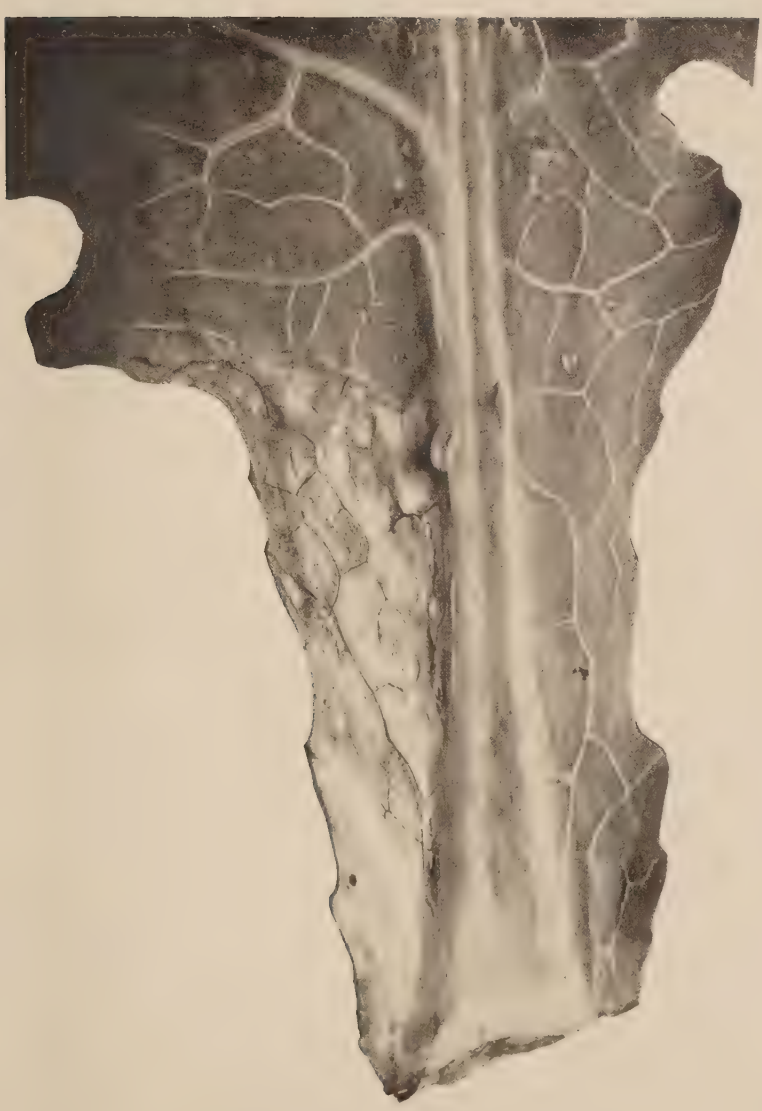

PLATE II.—CABBAGE LEAF AFFECTED WITH BLACK ROT ON THE LEAF STALK CLOSE TO THE STEM.

served that the plants were very uneven in size.[13] Some grew vigorously while others, scattered here and there through the field, were small and some of them were wilting in spite of the fact that the ground was saturated with water. An examination of the wilted plants showed the lower portion of the tap-root to be dead and the fibro-vascular bundles in the stem blackened as in black rot. If this bundle blackening was really due to *Pseudomonas campestris* (which was proven in one instance) the plants must have been infected through the roots. This point will be further investigated during the coming season.

If root infection is as common as it appears to be it is a very important factor in the treatment of the disease. Root-infected plants can not be cured and no method of treatment which deals only with the parts of the plants above ground, such as leaf-pulling or spraying, can give any protection against root infection.

Infection occurs at base of leaves close to the stem.—One object in removing affected leaves is to prevent the disease from passing down the fibro-vascular bundles into the stem where it is beyond control. When infection occurs on the margin of the leaf at some distance from the stem this is easily accomplished; but the writers have found that infection often occurs on the basal portion of the leaf within one or two inches of the stem and gets into the stem before it is observed. (See Plate II.)

Many cabbage leaves have no well-defined petiole. Toward the base the stout midrib is bordered on either side by a narrow strip (one-fourth to one inch wide) of thin leaf tissue. Infection is as likely to occur here as on any other portion of the leaf and is apt to be overlooked because the closely-overlapping leaves hide it. In a few days the disease has gained access to the stem and then its progress can not be checked. This is one of the difficulties in the way of the successful application of the leaf-pulling treatment.

[13] In this connection it is interesting to note Russell's observation (Loc. cit. p. 39) that: "In some cases where the plants were small the disease had established itself in the stem, but in the majority of cases only individual leaves were affected." This was on September 1, when the disease was "just beginning to make its appearance." Probably, the small plants had been infected through the roots and their small size was the consequence of such infection.

The black rot germs are widely distributed.—As yet there is very little exact knowledge concerning the mode of dissemination of the black rot germs. Either the germs are now abundant in nearly all soils in the cabbage-raising sections of the State, or else they are disseminated with remarkable facility. Although the virulence of the disease varies greatly in different fields it is rare to find a field wholly exempt if the season is at all favorable for the disease. It is very often destructive in fields which have never before grown cabbage or other cultivated plants of the cabbage family.

Because of the wide distribution of the disease germs it is apparently useless to attempt to prevent the spread of the disease by the removal of diseased plants. At least, no success is to be expected until it is definitely known how the germs are disseminated.

EXPERIMENTS ON CAULIFLOWER.

During the past four seasons in which the cabbage experiments have been in progress at Phelps similar experiments have been carried on with cauliflower on Long Island; but these experiments have been barren of results because of a lack of the disease. During four consecutive seasons there was not enough black rot in the experiment fields to give the leaf-pulling treatment a fair trial. Nevertheless, it will be abandoned. Since it is a pronounced failure with cabbage it is altogether likely that it will not succeed with cauliflower for the same reasons.

On cauliflower, spraying with resin-bordeaux mixture[14] has also been tried during four seasons. Owing to a scarcity of the disease the results are inconclusive but sufficiently encouraging to warrant the continuation of the experiments.

[14] For the preparation of resin-bordeaux mixture see Bulletin 188 of this Station, page 247, footnote.

AN EXPERIMENT TO DETERMINE HOW THE REMOVAL OF THE LOWER LEAVES AFFECTS THE YIELD OF CABBAGE PLANTS.

In the experiments on the treatment of black rot by the removal of diseased leaves it soon became evident to the writers that whenever there was a destructive outbreak of the disease it would be necessary to remove large numbers of leaves and this raised the question as to what would be the effect on the yield of the plants.

The leaves of plants are important organs. It is in the leaves that the inorganic food substances taken from the soil are worked over into organic compounds which can be used by the plant to make further growth. If the leaves are destroyed by disease, insects or other agency the growth of the plant is checked. This is a general law among leafy plants and there seems to be no good reason for believing the cabbage plant to be an exception to the rule. However, it is stoutly maintained by some farmers that the removal of a few of the lower leaves of cabbage plants is not only harmless but positively beneficial to the plants and tends to increase the size of the heads.

In order to get definite information on this point the following experiment was made at Phelps, N. Y., in 1900: On the untreated half of the acre used for black rot experiments in 1900 (see p. 54) sixty-four rows were designated for use in the experiment under consideration. There were 35 plants in each row. They were of the variety Danish Ball Head and transplanted July 3. From each plant in every alternate row the lower leaves were removed as follows:

August	9,	2 lower leaves removed from each plant.
"	15,	2 " " " " " " "
"	30,	2 " " " " " " "
September	5,	1 " " " " " " "
"	12,	1 " " " " " " "
"	19,	1 " " " " " " "
"	27,	1 " " " " " " "

In the course of the season ten lower leaves were removed from each plant in the alternate rows. On November 12 the crop was harvested and the product of each row weighed separately. The results are shown in the following table:

TABLE VI.—YIELD OF CABBAGE AS AFFECTED BY REMOVAL OF LOWER LEAVES.

Leaves removed.			Check.		
Row.	No. marketable heads.	Weight in lbs.	Row.	No. marketable heads.	Weight in lbs.
1	10	33	2	16	56
3	12	31	4	23	102
5	17	56	6	26	103
7	13	42	8	20	81
9	20	62	10	27	110
11	18	53	12	23	87
13	21	65	14	24	103
15	21	67	16	23	100
17	13	41	18	23	91
19	15	57	20	21	80
21	12	34	22	19	77
23	14	46	24	21	79
25	14	45	26	20	77
27	16	58	28	27	104
29	16	56	30	24	97
31	14	47	32	21	89
33	17	56	34	18	80
35	20	66	36	22	95
37	10	31	38	24	98
39	18	58	40	25	104
41	14	44	42	26	96
43	19	68	44	25	95
45	13	42	46	22	82
47	16	48	48	20	78
49	20	60	50	21	77
51	17	58	52	24	98
53	17	55	54	23	86
55	13	40	56	18	61
57	10	28	58	17	60
59	17	61	60	15	49
61	8	23	62	20	72
63	4	10	64	8	25
Totals	479	1,541		686	2,692

In every instance, save one, the check row gave a larger number of marketable heads than did the adjacent row from which the leaves had been removed. The average weight of the heads was also greater. The difference in total yield was 1151 pounds, which is at the rate of three tons per acre. Expressed in terms of percentage the reduction in yield due to the removal of ten leaves from each plant was 42.8 per ct.

CONCERNING THE PREVENTION OF BLACK ROT.

No practical treatment for black rot has yet been discovered. It has been shown that the leaf-pulling treatment instead of being beneficial is positively harmful. Rotation of crops affords little if any protection against the disease. Placing the seed bed on soil which has never grown cabbage or related plants is a good practice, but it remains yet to be proven that it is of any real value as a preventive of black rot. Spraying with resin-bordeaux mixture is, perhaps, worthy of trial, but can not be relied upon to control the disease.

The virulence of the disease depends largely upon weather conditions, and it is unfortunate that the conditions most favorable to the growth of cabbage are also the most favorable to the disease. Rapidly growing plants are especially liable to be attacked.

It appears to the writers that before much progress can be made toward the control of the disease it will be necessary to determine more definitely how the germs spread from plant to plant and field to field; also, to what extent they live over winter in the soil, to what extent root infection occurs and whether the disease is transmitted through the seed.